# Chemistry I

## Atomic Structure Notes

# Introduction

- History behind atomic models & parts
- Discoveries that helped in the discovery
- The parts of the atom
- Models of the Atom

# Atomism

- Somewhere about 400 B.C., two Greek philosophers came up with the idea of the atom. The two Greeks were Leuicppus of Miletus and Democritus of Abdera (known here after as the two dead Greek dudes).

# Atomism

- Their theory has five statements:
  1. All matter is of atoms, which are bits of matter two small to be seen. The atoms cannot be broken into smaller pieces.
  2. There is empty space between atoms.
  3. Atoms are completely solid (no space within the atom).
  4. Atoms are homogeneous, with no internal structure.
  5. Atoms are different in size, shape, and weight (added by Epicurus later).

# Atomism

- Summary:
  - All did not embrace this idea. Aristotle and others wrote against this idea. The early Catholic Church also did not like this theory. So it kind of disappeared.

# Atomic Theory

- John Dalton (1766-1844): The Father of the Chemical Atomic Theory
- He published his theories on the atmosphere and gas behaviour in a book titled *A New System Of Chemical Philosophy*. Only in the last few pages (Chapter III) did he discuss his atomic theory.

# Atomic Theory

- Modern scholarship has identified four basic ideas in Dalton's chemical atomic theory
  - 1) chemical elements are made of atoms
  - 2) the atoms of an element are identical in their masses
  - 3) atoms of different elements have different masses
  - 4) atoms only combine in small, whole number ratios such as 1 :1, 1:2,2:3 and so on.

# Daltons Theory

- **1) Elements are made of atoms.**
  - Elements are made up of minute, discrete, indivisible, and indestructible particles called atoms. These atoms maintain their identity through all physical and chemical changes.

# Daltons Theory

- **2) The atoms of an element are identical in their masses.**
  - Atoms of the same element have the same properties, such as weight. Atoms of different elements have different properties, including a different weight

# Daltons Theory

- **3) Atoms of different elements have different masses**
  - In other words, while it was claimed atoms of different elements had different weights, no one could figure out what the different weight values were. Dalton was the first to do so.

# Daltons Theory

- **4) Atoms combine in small, whole number ratios.**
  - Chemical combination between two or more atoms occurs in simple, numerical ratios (i.e., 1 to 1, 1 to 2; 2 to 3; etc.).
  - This point gives immediate explanation to the *Law of Definite Proportions* announced by Joseph Louis Proust in 1797.

# Daltons Theory

- This law is sometimes called the *Law of Constant Composition*. In a modern textbook, it is:
  - A given chemical compound always contains the same proportion by mass of its constituent elements.
  - A different way to say it:
    - The relative amount of each element in a particular compound is always the same, regardless of preparation or source.

# Daltons Theory

- Dalton discovered the *Law of Multiple Proportions*, another law that is easily explained by his atomic theory.
  - Dalton discovered this law while studying some of the oxides of nitrogen.
  - The law, in modern terminology, is:
  - Atoms of the same element can unite in more than one ratio with another element to form more than one compound.

# Daltons Theory

- A fifth idea implicit in Dalton's theory, but usually not discussed is this:
  - atoms can be neither created nor destroyed. An element's atoms do not change into other element's atoms by chemical reactions.

# Other important discoveries

- 1858- William Geissler invents the vacuum pump. This allows scientist to study the flow of electricity in sealed glass tubes w/o air. They studied what was called cathode rays.

# Other important discoveries

- 1879- William Crookes makes the 1st "cathode ray tube". Finds that cathode rays appear to be streams of negative particles because a negative charge builds on the targets struck by the rays.

# Other important discoveries

- 1886 Edward Goldstein makes a “canal ray tube”. He observes a ray that goes in the opposite direction than the cathode ray. Ray creates a positive charge when it hits metal. Concludes that canal rays are streams of positive particles.

# Other important discoveries

- 1891- George Stoney estimates the charge on this unknown negative particle. Calls it the “electrine” which later becomes the “electron”

# The Electron

- 1897- J.J. Thomson calculated the charge to mass ratio for cathode rays. Figures the rays to be made of tiny particles that we call electrons.(1899 completes work by measuring the charge on the electron)

# The Electron

- 1911- R. A. Millikan directly determined the charge on the electron with his “oil-drop” experiment. Once the charge was known, the mass could be calculated.
  - The electron is assigned the charge of –1.

# The Electron

- It turned out to be 1/1827th of the mass of a hydrogen atom. (The mass to charge ratio of a hydrogen atom could also be obtained by similar measurements. )

- If all atoms contain negatively charged electrons, which contribute almost nothing to the mass of the atom, then where is the positive charge needed to make the atom have an overall neutral charge?

# The Nucleus

- 1911- Ernest Rutherford found that the atom has a small dense nucleus at the center. Later determines the nucleus to have a positive charge.

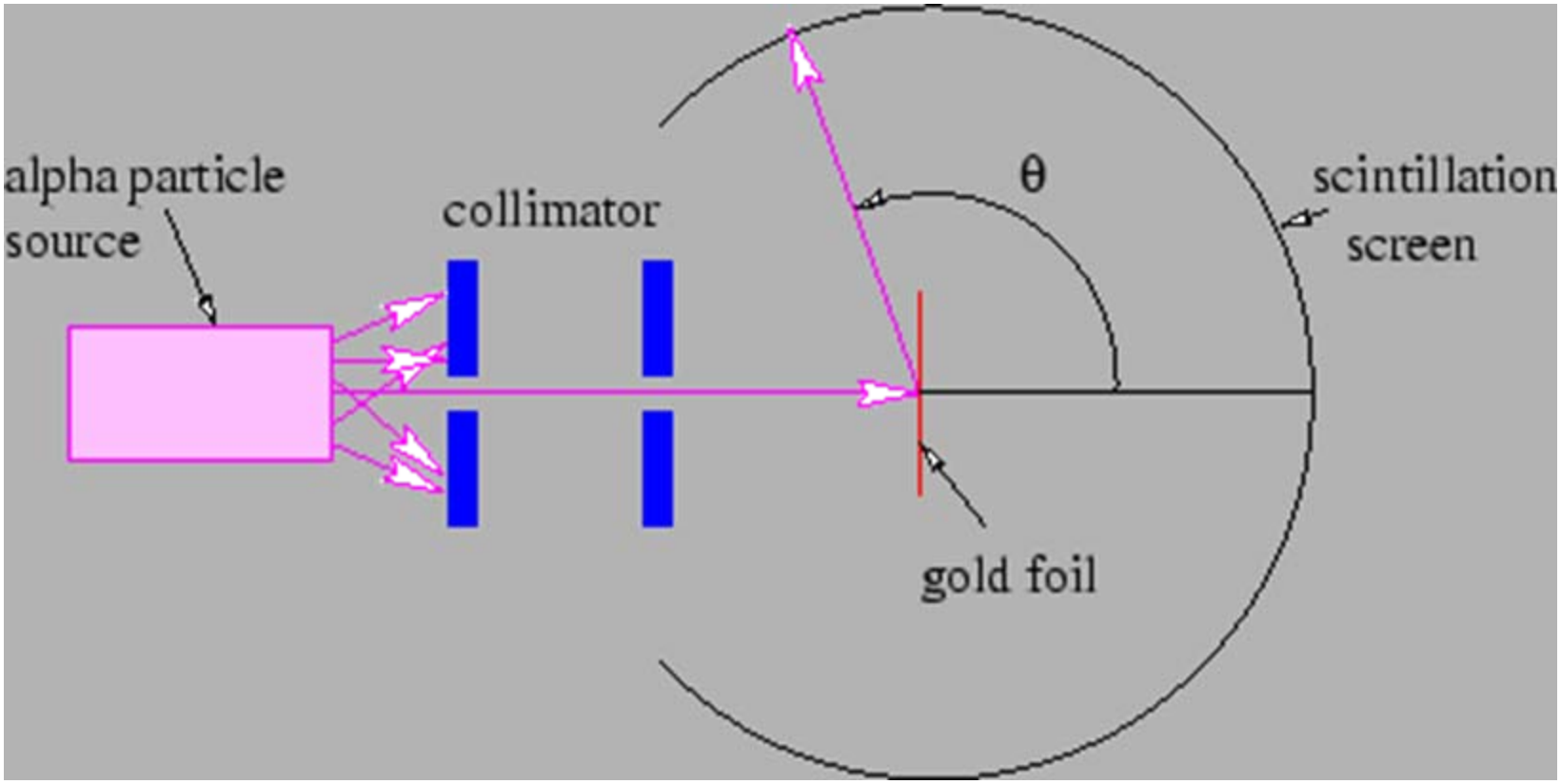
# Rutherford's Gold Foil Experiment

The experiment:

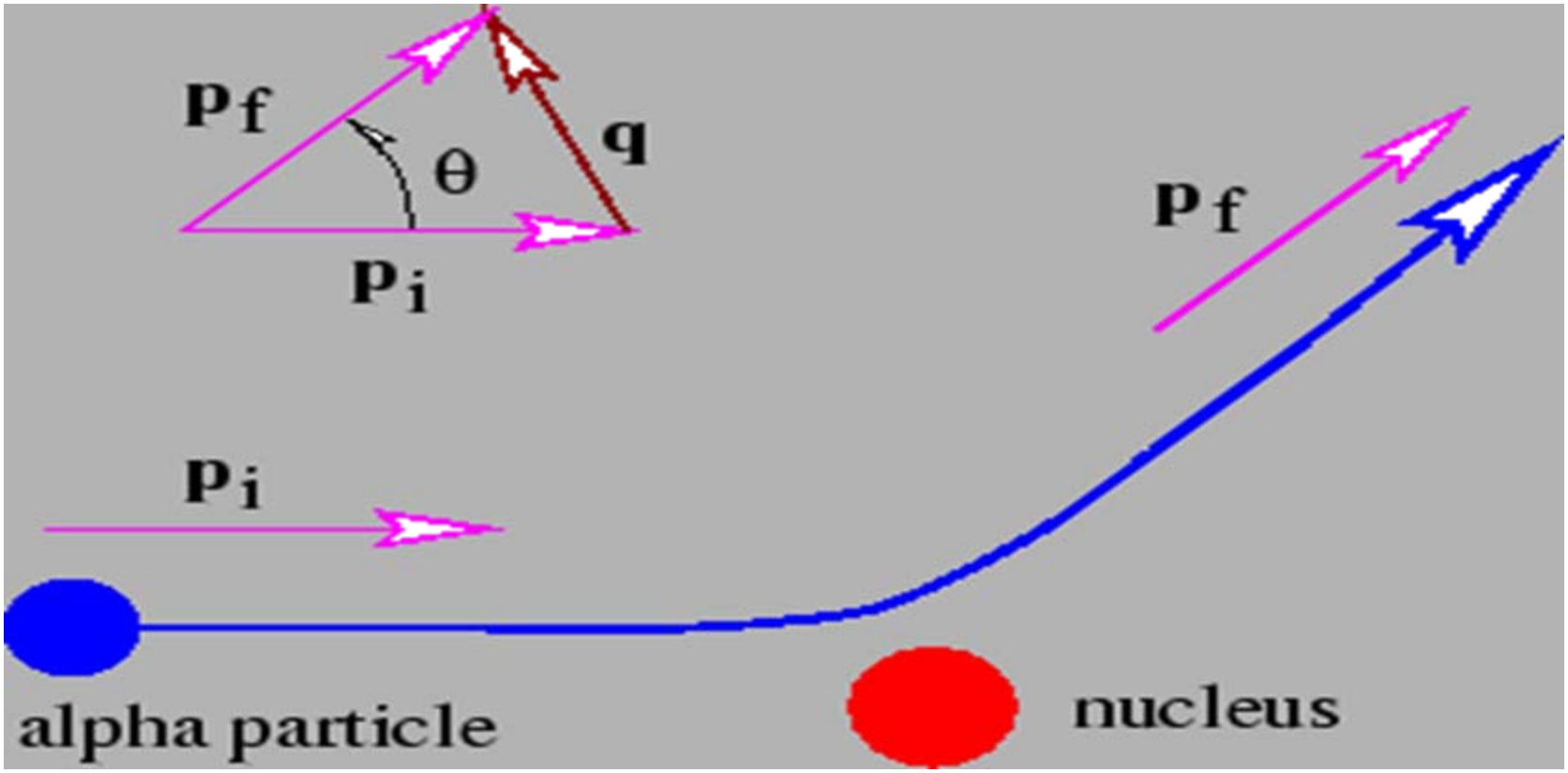
Alpha particles were fired at thin gold foil.

Alpha particles are helium atoms w/o electrons and have a positive charge.

# Gold Foil Experiment



# Alpha particle reflection



# Gold Foil Experiment

- Results:
  - Most of the alpha particles went straight through the gold foil.
  - Some of the alpha particles were deflected.
  - Some like 1 or 2 in several thousand bounced straight back at the source

# Gold Foil Experiment

- Rutherford's conclusions:
  - Atoms are mostly empty space.
  - The center (nucleus) is very dense.
  - The nucleus has a positive charge.

# More on the Nucleus.

- **Henry Moseley** (1913-14) investigated the characteristic frequencies of X-rays produced by bombarding each of the elements in turn by high-energy cathode rays (electrons). He discovered a mathematical relationship between the frequency and the atomic number (the "serial number" in the periodic table).
- Calculated the positive charge on the nucleus.

# Atomic number and Protons

- This must mean that the atomic number is the number of positive charges carried by the nucleus. Therefore, the atomic number is the number of protons in the nucleus of an atom.
- Moseley was killed in action at Gallipoli in the First World War.

# The neutron

- Scientist now had two parts of the atom but they could not account for the mass. Rutherford had predicted its existence but had no laboratory proof of its existence.

# The neutron

- 1932- James Chadwick discovers the neutron.
  - Bombarded small atoms(Be) with alpha particles and observed “neutral rays” which were particles similar in mass to  protons but had no charge.
  - Hence the neutron ( 1st named in 1921by William Harkins)

# Atomic Structure: Atoms

- Atoms are made of protons, neutrons and electrons. The protons and neutrons are held together in the nucleus by strong nuclear forces. The nucleus is a dense positively charged area at the center of the atom. The nucleus contains 99.9 % of the mass of an atom. Now, the electrons are somewhere around the outside of the atom in a region called the electron cloud. The size of the atom is about 1 X $10^{-13}$ centimeters.

# Atomic Structure: Atoms

| Particle | Symbol | Charge | Mass | Location | AMU |
|---|---|---|---|---|---|
| Proton | $p^+$ | +1 | $1.673X10^{-24}$ g | Nucleus | 1 |
| Neutron | $n^0$ | 0 | $1.675X10^{-24}$ g | Nucleus | 1 |
| Electron | $e^-$ | -1 | $9.109X10^{-28}$ g | Electron cloud | 0 |

# Atomic Structure: Atoms

- Terms:

1. Atoms are the smallest units of an element that retain the properties of the element.
2. Isotopes are atoms of the same element with different masses due to a difference in the number of neutrons.
3. Neutral atoms have no charge (zero) because they have equal numbers of protons and electrons.

# Atomic Structure: Atoms

4. Ions are atoms of an element with a charge that can be positive or negative. This is due to a difference between the number of protons and electrons.
5. Mass number is the sum of the number of protons and the number of neutrons.
6. Atomic mass is the average mass of the atoms of an element (all isotopes). Is measured in atomic mass units (A.M.U.)
7. Atomic number is the number of protons an atom has in the nucleus. This number is unique for each element.

# Atomic Structure: Atoms

- The Math:
- # protons = the atomic number(see Periodic Table).
- mass# = # protons + # neutrons
- therefore # neutrons = mass # - atomic #

- Charge on an atom: find the difference between the # protons and # electrons
- this will be 0 or a small positive or negative number.
- Fewer electrons will give an atom a positive charge.
- More electrons will give an atom a negative charge.